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144-151:

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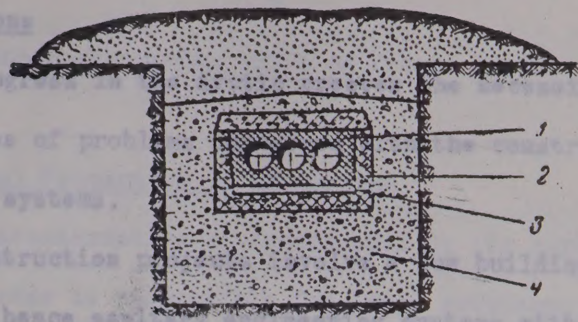

Fig. 1. Combined Installation of Heating and Water Mains in a Buried Prefabricated Reinforced Concrete Conduit Showing the Conduit and the Manner in Which it is Placed in the Soil: 1. Granulated Mineral Wool Thermal Insulation; 2. Prefabricated Reinforced Concrete Conduit in Sections; 3. Drainage Channel for Maintaining Thermal Insulation in a Dry State; 4. Mixture of Gravel and Pebbles with Sand-Clay Binder Filling Pores.

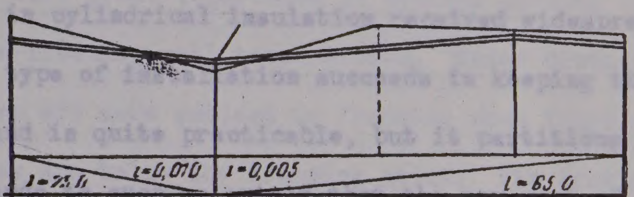

Fig. 2. Approximate Construction Profile Showing Emergence of Installation from Ground at Low Point: 1. Point of Discharge of Fluid from Conduit Drainage Channel onto Surface of Ground.

Moisture Content by Vol. % / Влажность объемная, %	Thermal Conductivity (λ) / Теплопроводность термоизоляции (λ)							
	1 Пенобетон (γ = 400)		2 Шлаковая вата (γ = 400)		3 Торфоплиты (γ = 250)		4 Опилки (γ = 300)	
	> 0°	< 0°	> 0°	< 0°	> 0°	< 0°	> 0°	< 0°
5	0,135	0,205	0,081	0,090	0,075	0,083	0,138	0,143
10	0,174	0,295	0,095	0,110	0,098	0,113	0,157	0,167
15	0,202	0;381	0,103	0,130	0,119	0,143	0,176	0,191
20	0,229	0,464	0,120	0,150	0,139	0,173	0,195	0,215
25	0,255	0,542	0,132	0,170	0,159	0,203	0,214	0,234
30	0,280	0,618	0,144	0,200	0,179	0,233	0,233	0,258

Table 1. Thermal Conductivity of Thermal Insulation as a Function of Moisture Content for Above- and Below-Freezing Temperatures (°C.). 1. Foam Cement; 2. Scoriaceous Wool; 3. Processed Peat; 4. Sawdust; γ- Volumetric Weight of Thermal Insulation.

Construction Conditions

Construction progress in the Arctic creates the necessity of working out and analyzing a series of problems concerned with the construction of exterior sanitary engineering systems.

Most Arctic construction projects involve a low building density and low-story structures and hence sanitary engineering systems with scattered lines of very small diameter. This type of construction requires simply-designed installations which are in economic relation to the major works. The use of conduits of the access or semi-access types and of other types of construction invloving a large cross section would be unsuitable because of their relatively high cost. At one time the installation of pipelines on the surface of the ground in temporary-type wooden boxes or in cylindrical insulation received widespread application on such projects. This type of installation succeeds in keeping the frost in the foundation material and is quite practicable, but it partitions the streets, thoroughfares and courtyards to such an extent that the movement of traffic becomes impossible without the construction of bridges and crossings at the pipelines.

All these circumstances cause designers and builders to attempt:

1. To reduce the size of an aboveground installation as much as possible, while maintaining the natural thermal regime in the foundation material;

2. To determine the feasability and the suitable limits of application of a buried installation in unstable soil and to work out required measures to prevent settlement in unstable soil.

Buried installations present the principal interest as they avoid (on the whole, if not completely) the congestion of settlements built on unstable ground by aboveground boxes. The essential factors which can exert an influence on the operation of sanitary engineering systems should be taken into account when dealing with this problem. Neglecting these factors leads not only to defects in the systems themselves, but also, as experience shows, to the partial coll-

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apse of buildings and other structures built on frozen ground in the vicinty of the lines.

Influence of the Physical Properties of the Ground

One of the main characteristics of frozen soil is its high moisture content (ice content). This factor is responsible for large settlements when the material under pipelines thaws and when seasonal cycles occur, and is frequently the cause of undesirable profile changes within the system (due to uneven settlement along the installed gradient line), disruption of pipe joints, rupturing of manholes, and other damage; the extent of the damage increases until the thermal and moisture content regimes of the surrounding ground have become stabilized.

Another feature of very great importance in systems serving low-story buildings is the presence of below-freezing soil temperatures. Water distribution and sewage collection systems are more subject to freezing when fluid discharges are low and soil temperatures are below the freezing point. The provision of special measures to ensure that these systems will operate when the surrounding medium is at below-freezing temperatures thus become obligatory.

The use of soil as a thermal insulating medium does not yeild a satisfactory result for pipelines up to 150 millimeters in diameter, in the majority of cases.

Insulated pipeline installations are adversely affected by the impermeable character of frozen soil. Because of this soil property, moisture which accumulates in the thawed zone along the pipeline cannot escape, except in cases where flow along a sloping pipeline through pervious soil and the thermal insulation and along a drainage channel (if provided) is feasible. Groundwater formed during the thawing process and flowing at a steep slope along and under a pipeline can cause uneven settlement by eroding fines and transfering heat to the soil of the foundation. If moisture is not removed it accumulates in the thermal insulation of the buried pipeline (unless the thermal insulation has hydrophobic properties),

leading to a sharp increase in the heat loss and to freezing when low temperatures occur.

Initial Data

The importance of the above features varies greatly owing to the great variety of geological, frost and climatic conditions found in different regions of the Arctic. This fact makes it necessary to obtain sufficient data to be able to properly select the installation method to be used in each region. A gap between thermal engineering computations and structural considerations on the one hand and the authenticity of the physical soil data on the other is frequently left by the many organizations designing sanitary engineering systems.

Soil settlement due to thermal effects is naturally one of the main indices of the practicability of buried pipelines or channels (with non-refrigerated foundations) and of the necessity of taking measures to prevent settlement and heaving. In the absence of ice lenses and ice zones (which are dangerous with respect to gully formation) along the line, installations are buried, provided that measures to prevent settlement are economically feasible and that the thawing of the frozen foundation material under major works can be prevented.

Measure to Prevent Settlement

Methods of reducing the depth of the thermal influence of an installation deserve close attention in connection with measures designed to prevent settlement. Laying conduits as shallow as possible is one of the procedures which is suitable for all types of systems. If gravity sewers in unstable soil must be laid at great depths because of their slope, it is better to sacrifice the advantages of a gravity system and to construct a group of collecting receptacles and pressure lines at a shallow depth than to construct a deeply-buried system which may or may not operate properly and which necessitates a great deal of labor when repairs are required.

Another no-less-effective method of reducing the depth of thawing under an

installation is the construction of a thermal insulation shield with a high thermal resistance directly under the installation. Primary insulation material can be used for this layer in the case of a conduit group installation with tamped thermal insulation. In the case of a single-line pipeline with no conduit, a suitable solution is the laying of a slab of hydrophobic material such as foam glass under the conduit; bituminized peat can be used if it is impossible to obtain the former material.

The thermal influence of an installation on the soil can also be reduced by decreasing the temperature inside pipelines. The temperature of water from bath houses and laundries, for instance, is from 30 to 32 degrees C., whereas this temperature can be reduced to from 18 to 20 degrees C. in a heat exhange-recovery unit, reducing the intensity of heat flow in the ground almost 1.5 times.

Preserving Frost Under Major Structures

In order to preserve the frost in unstable soil under buildings, the central heating, water and sewer services are placed aboveground and are covered by sidewalks. Any fluid which enters the service conduit is carried away from the building in a drainage channel on the bottom of the conduit.

The lines of sanitary engineering systems are installed not closer than from 6 to 8 meters from the walls of buildings, in order to preserve the frost under community buildings. Pipeline locations are generally fixed with respect to the foot of the walls of major structures.

The sudden discharge of a large quantity of hot water into the soil when a pipeline is damaged presents a great danger to the frozen foundations of buildings. Because of this factor, only steel pipe with welded joints is used for water and sewer lines. Steel pipe is preferable to cast iron as it is more dependable when settlements of the ground occur. Even a partial disturbance of the butt joint of a cast iron pipe can not only lead to sags along the line but can also

result in the thawing of frozen soil over a large zone. When lines are installed at steep slopes in pervious soil, fluid flow under the installation sometimes occurs; such action can result in the thawing of frozen soil below and to one side of the installation and in subsequent settlement. The construction of transveral impermeable cutoffs from argillaceous concrete, for instance, in the pervious soil is recommended in such cases.

Foundations of the Installation

The following installation methods are used in unstable soil:

1. Consolidation of soil or replacement of original soil by a soil mixture;

2. Separation of the installation from the foundation material in which soil deformation due to thermal effects can occur.

The first method is the most used in the case of water and sewer lines which are not placed in a larger conduit. The construction of a continuous foundation is possible, but the volume of earthwork is large and includes a considerable volume of unfrozen soil mixture used as trench backfill. The soil under the installation should be replaced, to the depth to which thawing can occur, by a soil mixture with the lowest possible porosity. The fact that coarse-structured as well as fine-grained and argillaceous soils are subject to heaving when completely saturated with moisture is well-known.

The hypothetical design case indicates the necessity of protecting the soil of the foundation of the installation from moisture effects by utilizing a mixture of coarse-structured soil and local fine soil, the latter of a type and in quantities required to fill the pores of the coarse-structured soil. The required depth of consolidated soil is reduced by using reinforced thermal pipeline insulation, especially under the pipeline.

The second method involves the aboveground installation of sanitary engineering systems utilizing either posts and piles embedded in the ground to a depth

at which the soil is in a stable condition or lateral beams the ends of which bear upon soil which is beyond the limits of the thermal influence of the pipeline. The amplitude of seasonal frost level fluctuations in the soil under a conduit or channel can attain large values in zones which are bare of snow and can result in soil heaving. Thus when the construction involves the use of posts or piles as supports, adequate preventive measures, such as sliding boxes, sleeves or fill (a layer of non-swelling soil mixture) around the supports, are necessary.

Preservation of the Thermal Insulation Properties of the Installation

Retaining the thermal insulation properties and the impermeability of an installation surrounded by moisture-bearing soil is one of the conditions which is very important and difficult to fulfill in connection with the construction of systems in permafrost.

Hydrophobic thermal insulation of the necessary quality is desirable for such conditions, but is not as yet manufactured in large enough quantities. The use of hydrophobic thermal insulation would greatly facilitate the construction of water and sewer lines in the Arctic.

At the present time, bituminized compressed peat (sphagnum) is frequently used as thermal insulation for buried water and sewer lines not placed in a larger conduit. Sawdust is used as temporary insulation in certain cases, in the absence of other materials at the site. Organic thermal insulation must be compressed and treated with bitumen in order to reduce the transfer of heat through it should be moistened; in its loose state the transfer of heat would be increased by moisture migration effects.

Prefabricated conduits with compressed granular mineral wool thermal insulation are used for combined pipeline installations; a series of measures to maintain the insulation in a dry state are required when the conduits are buried in impermeable soil. A buried combined installation of heating and water lines in a

prefabricated reinforced concrete conduit is shown on Figures 1 and 2. Moisture which filters through the insulation flows along a drainage channel situated inside the conduit. Conduits of this type are buried at a shallow depth; the drainage channel discharges by gravity onto the surface of the ground at an outlet situated at a low point in the system. Combined installations of the "utilidor" type, used on Arctic projects in the U.S.A., are provided with catch basins from which collected moisture is pumped out when drainage channels do not discharge onto the surface of the ground. This solution requires chambers with pumps which complicate both the construction and operation of systems. Topographical conditions at most community construction sites permit the selection of a point at which gravity discharge from the channels is possible. Aboveground sections of short lenth frequently occur when the height of the conduit (with compressed insulation) is not great.

The importance of ensuring that the thermal insulation of heating lines is maintained in a dry condition is evident from Table 1.

The "pipe-in-pipe" method of construction, presently used to some extent, is of considerable interest with respect to the preservation of the thermal insulation properties of an installation when freezing of saturated soils and moisture under pressure occurs. The annular section between the outer steel pipe which serve as a jacket and the inner insulated pipe is filled with a thermal insulation material such as granulated mineral wool. This design is used for single-pipe installations at road and thoroughfare crossings, for sewage outfall lines, and for isolated lengths of water lines and heating mains where conditions demand mechanical reliability and the smallest possible depth of insulation. The use of asbestos cement as the outer jacket in such installations is confined to experimental sections. The low mechanical reliability of this pipe, and hence the difficulty of transporting it, creates doubts with respect to the practical suitability of this material for remote regions of the

Arctic.

In the actual construction areas, various methods of utilizing local conditions and raw materials in connection with pipeline thermal insulation for temperatures less than 10 degrees C. can be adopted. Thus when water and sewer lines are placed along the bottom of an open channel or buried at a shallow depth, in areas which are covered with snow, the lines are under an insulating snow blanket during the winter period. Snow can be retained artificially along the pipeline route, in both suburban areas and zones which are not built up, in order to create such a snow cover. A layer of snow with a thickness of 0.3 meters is equivalent to a layer of soil with a thickness of approximately 1.5 meters, as regards thermal resistance.

The density of snow in the Arctic is approximately 0.25 at the beginning of the winter, but reaches values of from 0.40 to 0.50 at the end of the winter. Snow in the latter condition is so hard that it can be walked on without leaving a trace. The formula of Abels expressing the thermal conductivity of snow, λ, as a function of its density, δ, is:

$$\lambda = 2.4\delta \qquad \text{(kilo-calaries/square meter/hour/°C)}.$$

The use of snow as thermal insulation is not provided for in the design of construction projects, but can be adopted as a practical measure on the site when it is necessary to reduce heat losses from pipelines.

An overall solution to the important problem of ensuring that the thermal insulation properties of an installation are maintained would be the use of pre-insulated pipe which would be delivered to the construction site complete with a layer of rigid hydrophobic thermal insulation such as foam glass. Experience with similiar ensembles in connection with the construction of community central heating systems is well-known in the Soviet Union.

It is obvious that fabrication would have to be carried out at one of the plants producing thermal insulation. Such a plant would serve as a

transportation base for from 15 to 20 percent of the pipe used in Arctic construction. It does not appear possible to expect that thermal insulation fabricated at small works in the Arctic would be of a sufficiently high quality.

Since thermal insulation is required for all exterior sanitary engineering pipelines serving low-story buildings in regions of frozen soil, the need for one type of insulated pipe for heating, water and sewer lines in permafrost regions is evident.

Protection from Freezing

When Arctic settlements are provided with water supply and sewage disposal systems, a specific method of protecting the exterior pipelines from freezing must be inaugurated. This is especially important when low-story buildings are serviced because interruptions, even of short duration, or reductions in the discharge create pipeline freezing dangers, owing to the low water consumption per unit area and hence the small diameter of the lines and the relatively spread-out character of the system.

The choice of the method of protecting a water line from freezing is made simultaneously with the finalizing of the layout of the sanitary engineering systems and is taken into account when designing the installation and the pipeline thermal insulation. Preheating of the water is carried out at different points in the system, at water intakes (with first-stage pumping stations); when a water line is of considerable length, preheating points are sometimes installed along the line. The same principles are used in connection with the heating of fire storage and other reservoirs.

When settlements and industrial areas are provided with central heating systems, combined pipeline installations are used; the water line and the heating main are placed in a common conduit and provision is made for the necessary heat exchange between the pipelines so that temperatures in the water distribution system remain above the freezing point.

When water and sewer lines are laid in wet soil or in wet insulation and are not placed inside a large conduit, the resistance of the pipeline to freezing when the flow is stopped can be increased (that is, the cooling time can be increased) by utilizing the latent heat of fusion of moisture in the ground. The dimensions of a talik (thawed zone) decrease when the flow of water is stopped and increase when a flow of heat occurs.

The use of this thawed zone as a means of increasing the safety factor with respect to the freezing of pipelines buried at a shallow depth cannot be depended upon in practice, however, because of soil moisture content variations (presence of dry, drained sections) and the low freezing temperature of soil moisture (as low as from -2 to -3 degrees C.).

Almost all elements of a sewage collection system are protected from freezing by the heat content of water discharged into the sewers. Calculations of the heat losses in all elements of the system are used to fix the distribution of the water used for heating the sewage collection system. Inspection-type manholes are used instead of trough-type manholes in order to reduce heat losses from the manholes of sewage collection systems. Combined installations in which sewer lines and heating mains are placed in the same thermal insulation are employed as a method of protecting sewer lines from freezing in certain cases (favourable topography and convenient sewer service connections). The heat loss from the protected pipe is compensated for by providing adequate heat exchange between the pipelines. In one Arctic project this method of installation is carried out, in conformance with sanitary regulations, by placing the sewer line and the return heating main in one conduit and the water line and the supply heating main in another.

The special features discussed above are used in planning the construction and operation of sanitary engineering systems serving low-story buildings in Arctic areas.

End of Article

TRANSLATOR'S NOTES

The following extracts from Russian-English, Russian and English dictionaries involve words which are not in the Russian-English dictionaries or which require special clarification.

The numbers in parentheses refer to the publications listed at the end of the extracts.

The words in quotation marks are Russian words which have been translitered according to the system recommended by the U.S. Library of Congress.

Hydrophobic ("Gidrofobnyy")

(3) "Gidrofobnyy": Hydrophobic.

(3) "Gidrofobnost'": Hydrophobic nature.

(6) Hydrophobic:

(a) Pertaining to or effected with hydrophobia.

(b) Not readily absorbing water, or being adversely affected by water, as a hydrophobic colloid.

(1) "Gidrofobnost'":

(a) Inability of dispersed particles to combine with molecules of water serving as the dispersing medium.

(b) Property of a solid body not to be moistened by water. The natural hydrophobic properties of a number of valuable minerals are used during concentration in a series of floatation processes.

Peat (Torf)

(3) "Torf": Peat, turf.

(5) Peat:

(a) A piece of turf cut for use as fuel.

(b) Semicarbonized vegetable tissue formed by partial decompositon in water of various plants, especially mosses of the genus sphagnum.

(5) Sphagnum:

(a) Any of a genus (Sphagnum) of mosses, sole type of a family

(Spaghaceae); the peat mosses.

(b) A mass of these plants used by florists in packing, potting, etc., or in making surgical dressings and similar pads.

(5) Turf:

(a) The upper stratum of earth and vegetable mold filled with the roots of grass and other small plants so as to form a kind of mat; sward; sod; also a piece or slab of this; a sod.

(b) Peat, especially when used or ready for fuel.

Processed Peat ("Torfoplity")

"Torf": See above.

(3) "Plita":

(a) Plate, slab, tile.

(b) Flag, flagstone.

(c) Range, stove.

(3) "Plitka":

(a) Slab, cake, block.

(b) Tile.

(c) Scale, flake.

(1) "Torfoplity": Thermal insulation material prepared from peat which is compressed and treated by a special thermal process which cements the peat fibres together. The volumetric weight of processed peat is not more than 250 kilograms per cubic meter. Processed peat is not attacked by merulius lacrimans (a timber-destroying fungus) and only smoulders when burnt. Processed peat covered with plaster is used as thermal insulation for walls and ceilings.

Foam Glass ("Penosteklo")

(3) "Peno-" (Prefix): Foam, froth.

(3) "Steklo": Glass.

(1) "Penosteklo": Light porous thermal insulation material developed by Professor I. I. Kitaygorodskiy, a Soviet Scientist. Foam glass is a porous vitreous mass filled with cells from 0.25 to 0.5 millimeters in size separated from one another by thin walls.

The fabrication processes include securing vitreous material by the fusion of rock, reduction to fragments, interblending in a gasifier (with up to one percent carbon or limestone), and heating to a temperature of from 700 to 800 degrees C. The gases given off at this time cause the mass to expand and small cells to form. The volumetric weight of foam glass is from 250 to 600 kilograms per cubic meter, its coefficient of thermal conductivity is from 0.09 to 0.15 kilo-calories per meter per hour per degree, and its ultimate compression strength is from 20 to 150 kilograms per square centimeter. Foam glass is easily sawn, cut or drilled and can be applied without special preparation. Blocks and slabs of foam glass are used as thermal insulation and sound insulation for walls, ceilings, partitions, etc,

Foam Concrete ("Penobeton")

(3) "Peno-" (Prefix): Foam, froth.

(3) "Beton": Concrete.

(3) "Penobeton": A foamy cement.

(4) "Penobeton": Gas concrete.

(1) "Penobeton": Porous concrete with a large number of small pores. Foam concrete has a specific weight of from 300 to 1,200 kilograms per cubic meter and a corresponding ultimate compression strength of from 15 to 100 kilograms per square meter. Foam concrete is prepared mechanically by mixing cement paste with foam. The foam is obtained by utilizing a special foaming agent composed of an aqueous solution of an adhesive rosin emulsion, saponin, etc. Light foam concrete with a volumetric weight of from 300 to 500 kilograms per cubic meter is used for thermal insulation. Structural and thermal insulating slabs of foam concrete are used in filling the spaces between ceiling beams and in the construction of walls and partitions. Reinforced foam concrete slabs and panels (with steel reinforcing) are used as thermal members for the roofs and walls of buildings.

(2) "Penobeton": Porous concrete construction material which is a mixture of cement solution or paste with foam obtained by a special mixing operation utilizing a foaming agent prepared from rosin soap and organic paste. When the mixture of cement paste (or solution) and foam has hardened a strong framework of thin walls separating air cells from one another is formed. Foam concrete has a low volumetric weight (from 300 to 600 kilograms per cubic meter) and low thermal conductivity owing to its high porosity. From 350 to 450 kilograms of cement, from 0.25 to 0.30 kilograms of joiner's glue, from 0.12 to 0.15 kilograms of rosin, one kilogram of household soap and 250 liters of water are used in the fabrication of one cubic meter of foam concrete mixture. Special foam mixers are used to prepare the foam concrete mixture. Foam concrete products such as blocks are obtained by pouring the mixture into forms from which the products are removed when the foam concrete has solidified. Two network of steel wires from 4 to 6 millimeters in diameter are used in the

fabrication of reinforced foam concrete. Cement with hard quartz sand is added in this case. Reinforced foam concrete is fabricated in the form of slabs up to 3 meters long, approximately 0.5 meters wide and from 10 to 16 centimeters thick. Foam concrete is principally used as a thermal insulation material. Reinforced foam concrete can also be used as a construction material (for covering the workshops of industrial buildings, for instance).

Argillaceous Concrete ("Glinobeton")

(3) "Glina":

(a) Clay.

(b) (Met) loam.

(3) "Glinka": Clay.

(3) "Beton": Concrete.

(1) "Glinobeton": Carefully tamped and kneaded clay with the addition of crushed rock, gravel or pebbles used for seals (dams), isolating foundations from aggressive waters, etc.

(2) "Glinobeton": Mechanical mixture of clay, sand and gravel or crushed rock. The selection of the ingredients of the argillaceous concrete is based upon the criterion that the inert materials should be well coated with clay. An example of the ingredients of argillaceous concrete (by volume) is 40% gravel (from 0.5 to 2 centimeter size), 36% sand and 24% clay. Argillaceous concrete is used as a construction material for the impermeable sections of hydraulic engineering works. It is used in the construction of impermeable aprons for concrete, reinforced concrete and stone structures. In wooden structures it is also placed under the wooden planking of the apron section to provide a high impermeability and stability with respect to uplift.

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